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IN THIS ISSUE:

*Segmental Gastric
Resection*

*Microsurgery in
Otology*

111

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CONTENTS

STAFF MEETING REPORTS

Evaluation of Segmental Gastric Resection

BY Peter A. Salmon, M.D., John F. Perry, Jr., M.D.,
and Owen H. Wangensteen, M.D., Ph.D. 378

Microsurgery in Otology

BY Lawrence R. Boies, M.D., and
Donald E. Kilgore, M.D. 391

FACULTY PUBLICATIONS 406

COMING EVENTS 408

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Staff Meeting Report

Evaluation of Segmental Gastric Resection*

Peter A. Salmon, M.D.† John F. Perry, Jr., M.D.‡
Owen H. Wangenstein, M.D., Ph.D.§

Until 1949, surgical treatment of diseases of acid peptic origin in the Surgery Clinic of University of Minnesota Hospitals was carried out by operations of the Billroth I and Billroth II type. But increasing dissatisfaction with these procedures has developed for a number of reasons: Distressing postgastrectomy symptoms occurred in 15 to 20 per cent of patients following the Billroth II operation, and these were severe in 4 to 5 per cent of all patients. Technical difficulty in dealing with a scarred duodenum has also been a disadvantage of this operation. In several clinics it has been shown that the Billroth I operation is followed by an incidence of recurrent ulcer of 11 to 17 per cent in long term follow-up studies^{1,2,3} on patients treated for duodenal ulcer, an occurrence which disqualifies the Billroth I procedure as an acceptable treatment for this disorder.

Difficult technical considerations in the surgical management of duodenal ulcer suggested the need for a better and simpler procedure. Failure of the antral exclusion operation had become well known to surgeons in this clinic. The antral exclusion operation accompanied by excision of the antral and pyloric mucosa was equally successful as the conventional Billroth II procedure. It was reasoned therefore that there must be an essential difference between retaining the antrum and excluding it. These deliberations suggested that restoration of alimentary continuity by gastro-gastrostomy rather than by gastrojejunostomy might avoid the technical difficulties of the Billroth II procedure in treating duodenal ulcer. A review of the literature revealed that such an operation was not new: Mikulicz⁴ in 1897 published the first paper concerning segmental gastrectomy; this was followed by reports of Riedel,⁵ Payr,⁶ and Judd.⁷ After Judd's paper in 1922, nothing was heard of segmental gastrectomy; the

* This report was given at the Staff Meeting of University of Minnesota Hospitals on March 14, 1958.

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procedure had fallen into disrepute, primarily because of recurrent ulceration and the problem of gastric emptying.

Payr's illustrations of segmental resection suggested that the excised gastric tissue constituted from 25 to 40 per cent of the entire stomach. The German surgeons, in employing segmental resection for gastric ulcer, failed to realize that transverse division of the stomach denervated the antrum and pylorus — a circumstance which accounted for delayed gastric emptying and some of the hourglass constrictions reported following use of the operation. Extensive segmental resection, therefore, with a concomitant Heineke-Mikulicz pyloroplasty was evolved at the University Hospitals primarily for the management of duodenal ulcer, and in the years 1949 through 1951, 94 of these operations were performed. In 1953, MacLean⁸ reviewed this series of 94 patients and found that while excellent protection against ulcer recurrence had been afforded, the dumping syndrome had occurred in a relatively large number of patients, some of whom had had severe symptoms. For this reason extensive segmental gastrectomy was temporarily abandoned, and other methods of attacking the problem were sought. Among these were modifications of the Connell fundusectomy,⁹ an operation which had been used in 13 patients in this clinic from 1938 through 1940. This operation of tubular gastrectomy with transverse gastroplasty was shown to protect against histamine in beeswax-induced ulcers in dogs; another group of patients was operated upon by this method, adding transverse gastroplasty, which had not been employed in the earlier series. Early evaluation of these patients by quantitative laboratory methods showed more acid and a lower pH in the gastric aspirate than expected. Further experiments with this operation in animals revealed hypersecretion from Heidenhain pouches, probably on the basis of a humoral mechanism which could be abolished by antral vagotomy.¹⁰ These observations together with a few clinical recurrences indicated that tubular gastrectomy was probably an unsatisfactory operation.

In 1955 a re-evaluation was made of a lesser segmental gastrectomy involving a considerably smaller resection than did the operations of this type performed from 1949 through 1951. Justification for these more limited excisions came from clinical and laboratory evaluation of the extensive segmental operation, which showed that the acid peptic activity of gastric juice was uniformly reduced to very low levels and that there were no recurrent ulcers. It appeared, therefore, that a lesser excision of stomach might provide equal protection. Because the optimal size of such a resection with low incidence of

secondary effects was, of course, unknown, two groups of more limited resections have been performed.

Clinical Material:

This report is a study of 94 extensive segmental resections performed during the years 1949 through 1951, together with 103 less extensive resections carried out from 1955 through 1957. The earlier and more extensive segmental operations involved removal of 90 to 95 per cent of the acid-secreting stomach, leaving 5 to 10 per cent of the stomach at the cardia and the gastric antrum. In all, 70 to 85 per cent of the stomach was removed. Among the two later groups of operations, one (moderate segmental resection) entailed excision of approximately 55 to 65 per cent of the stomach, and another (small segmental resection), 40 to 55 per cent excision.

Thus, since 1949 a total of 197 segmental gastrectomies of the three types have been carried out. The numbers of each type of procedure performed and the indications for operation are shown in Table I. The number of patients in the elective duodenal ulcer group, and the number of patients treated for gastric ulcer are sufficient to permit drawing valid conclusions from the data, but the small numbers of patients in the other groups (esophagitis, acute hemorrhage) make analysis less significant. In addition, patients treated for esophagitis and acute hemorrhage have been less extensively studied in the late postoperative period by quantitative laboratory tests. For these reasons, primary emphasis will be given in this analysis to results obtained in patients treated for duodenal and gastric ulcer.

TABLE 1
SEGMENTAL GASTRIC RESECTION: INDICATIONS FOR OPERATION

<i>Extent of resection</i>	<i>Extensive</i>	<i>Moderate</i>	<i>Small</i>
No. of patients	94	50	53
<i>Elective</i>			
Duodenal ulcer	65	33	43
Gastric ulcer	21	10	4
Esophagitis	2	2	5
<i>Emergency</i>			
Hemorrhage	6	5	1

Method of Study:

Preoperative and postoperative evaluation of patients has been carried out by conventional methods including medical history and

physical and radiographic examination. In addition, several tests designed to measure the ulcerogenic potential of the gastric secretion have been carried out. Included were triple histamine gastric analysis and eight-hour overnight collection of unstimulated gastric secretion for determination of pH, free acid, and pepsin content. In addition, a biologic perfusion test was used to measure the digestive activity of the unstimulated night gastric secretion; gastric juice adjusted to pH 1.6-1.7 and warmed to 37° C. is perfused through the esophagus of an anesthetized cat for two hours at a constant rate. The degree of resultant digestion is then measured on an arbitrary scale graded zero to five, grade zero representing normal unchanged mucosa, and grade five indicating perforation of the esophagus during perfusion. Grades zero through two represent little or no change, while grades three to five indicate significant degrees of digestion. Previous analysis has shown that only 9 per cent of gastric juice specimens from patients with no gastrointestinal disease cause grade three to five digestion of the cat esophagus when it is perfused in this manner, while 72 per cent of gastric juice specimens from untreated duodenal ulcer patients cause such severe degrees of esophageal digestion. The majority of preoperative specimens from patients with gastric ulcers thus far studied have produced digestion comparable to that seen with normal control patients.

Results:

Patients who underwent elective segmental gastrectomy for duodenal ulcer comprise the largest single category studied. Age and sex distribution for this group is presented in Table 2. There was no significant difference in the mean age values for the three groups, even though mean age of women with the small segmental operation was approximately ten years less than that of the other groups. The ration of men to women was approximately 4:1 in all except the moderate segmental group, where it was approximately 2:1. No unusual distribution of patients by age or sex therefore accounts for differences in the results which will be presented.

TABLE 2
ELECTIVE SEGMENTAL GASTRECTOMY FOR DUODENAL ULCER
AGE AND SEX DISTRIBUTION

	Extensive		Moderate		Small	
	Male	Female	Male	Female	Male	Female
No. of patients	52	13	21	12	34	9
Mean	56 yrs.	54 yrs.	50 yrs.	52 yrs.	56 yrs.	43 yrs.
Range	35-57 yrs.	44-69 yrs.	29-76 yrs.	37-68 yrs.	36-77 yrs.	18-61 yrs.

Table 3 shows the results of triple histamine gastric analysis. Preoperative free acid values exhibit no significant variations among the three groups; in fact, mean values are almost identical. Great reduction in free acid was achieved following all three gastric resections, the degree of this reduction correlating well with the extent of resection. Acid values are generally well below ulcerogenic levels, except in the small segmental group, when 25 per cent of patients exhibited free acid values ranging from 50 to 88 degrees. Achlorhydria following triple histamine was achieved in 90.4 per cent of patients after extensive segmental, in 57 per cent after the moderate segmental, and in 37 per cent after the small segmental operation.

TABLE 3
FREE ACID WITH TRIPLE HISTAMINE GASTRIC ANALYSIS
ELECTIVE SEGMENTAL RESECTION FOR DUODENAL ULCER

	Extensive			Moderate			Small		
	No. of Patients	Free Acid Mean	Free Acid Range	No. of Patients	Free Acid Mean	Free Acid Range	No. of Patients	Free Acid Mean	Free Acid Range
Preoperative	53	81°	38-133°	24	83°	40-118°	34	85°	53-150°
Postoperative	52	2.1°	0-30°	14	11.6°	0-46°	27	27°	0-88°

Results of analysis of eight-hour overnight gastric secretions following operation are shown in Table 4. Similar data from a group of untreated patients with duodenal ulcers, from a group of normal control patients, and from patients who had had Billroth I, Billroth II and the tubular operation are included for comparison.¹¹ Pepsin values following all three types of segmental gastrectomy were in the normal range; values for pepsin concentration were highest with the small segmental operation but still fell within the limits of values obtained from control patients.

In the extensive and moderate gastrectomy groups, free hydrochloric acid was present in only a few patients, and values were low. The pH values uniformly fell outside the range optimum for peptic activity. In the small segmental group one patient had a large amount of free hydrochloric acid (35mEq) in the night gastric aspirate, and five other patients had gastric secretions with free hydrochloric acid giving pH values of 2.0 or below. Although the values for pH in these six patients fell well within the range for maximum peptic activity, associated pepsin concentrations were low in the gastric secretions of all six. Nevertheless, these data do indicate that the small segmental gastrectomy did not control uniformly the ulcerogenic po-

THE MEDICAL BULLETIN

TABLE 4
ANALYSIS OF EIGHT-HOUR OVERNIGHT GASTRIC SECRETION
FOLLOWING OPERATION FOR DUODENAL ULCER

Category	No. of Patients	Pepsin		Free Hydrochloric Acid		pH	
		Mean	Range	Mean	Range	Mean	Range
Untreated Duodenal Ulcer	29	1.7 u/cc	.2-4.1 u/cc	19.04 mEq	0-110.40 mEq	2.1	1.2-4.2
Normal Controls	81	.9	.1-5.0	3.04	0- 21.23	3.7	1.4-7.4
Extensive Segmental	16	.16	.1- .6	0.49	0- 5.7	6.1	3.0-7.4
Moderate Segmental	17	.26	.1- .8	0.65	0- 5.0	5.1	2.4-7.0
Small Segmental	23	.48	.1-1.0	3.38	0- 35.0	3.6	1.2-6.5
Billroth I	10	.6	.1-2.0	1.00	1- 10.0	5.2	1.6-7.2
Billroth II	12	.5	.1-1.8	0	0	5.7	3.5-7.4
Tubular	20	.5	.1-1.4	4.60	0- 37.4	3.9	1.6-6.0

tential of gastric juice. Table 5 shows that whereas 29 per cent of patients with the small segmental operation had night gastric secretions with pH values of 2.0 or below, no patient in the moderate or extensive segmental group had gastric juice with pH values in this low range.

TABLE 5
pH VALUES OF UNSTIMULATED EIGHT-HOUR NIGHT SECRETION
FOLLOWING OPERATION FOR DUODENAL ULCER

Operation	Extensive	Moderate	Small
Total Number of Patients Studied	16	19	24
Per cent of total with pH 2.0 or below	0	0	29

Perfusion of the cat esophagus has been carried out with the gastric juice of all patients from whom sufficient volume of gastric juice had been obtained during overnight aspiration. Results of these investigations are given in Table 6. Included for comparison are similar data from patients with no gastrointestinal disease and from patients with untreated duodenal ulcer, as well as data from patients who had had other types of operation.¹¹ The degree of digestion produced decreases as the extent of resection increases. Following moderate segmental resection, the gastric juice of the majority of patients was close to normal, as far as this method of evaluation is concerned; following the extensive operation, uniform protection

against the ulcerogenic potential of gastric juice was obtained; but after the small segmental resection, 44 per cent of patients still secreted gastric juice with a digestive capacity within the range found in untreated duodenal ulcer. These data correlate fairly well with results of analysis of gastric secretion presented earlier.

TABLE 6
EIGHT-HOUR NIGHT SECRETION FOLLOWING SEGMENTAL GASTRECTOMY
FOR DUODENAL ULCER, PERFUSION OF THE CAT ESOPHAGUS

Category	Total Number of Patients	Grade of Digestion	
		0-2	3-5
Untreated			
Duodenal Ulcer	26	27%	73%
Normal Patients	56	91	9
Small Segmental	23	56	44
Moderate Segmental	18	88	12
Extensive Segmental	16	100	0
Billroth I	10	80	20
Billroth II	11	82	18
Tubular	19	84	16

To prove acceptable in treating peptic ulcer, an operation must result in a low incidence of distressing postgastrectomy complications. Table 7 shows that the frequency of the dumping syndrome can be directly correlated with the extent of the resection performed. The 3.4 per cent incidence of severe dumping reported for the moderate segmental group represents a single patient. Otherwise postgastrectomy symptoms have not occurred following the moderate and small resections. The frequency of dumping following the more extensive segmental operation has been relatively high, yet not grossly dissimilar from that experienced after the Billroth II procedure. The failure of patients to gain weight has also occurred following extensive segmental resection but has not been a problem associated with the moderate or small segmental operations.

TABLE 7
DUMPING SYNDROME FOLLOWING SEGMENTAL GASTRIC RESECTION
FOR DUODENAL ULCER

Category	Total Number of Patients	Severity of Dumping		
		None	Moderate	Severe
Extensive	63	73%	22%	5%
Moderate	29	96.6	0	3.4
Small	39	100	0	0

The incidence of recurrent ulceration must be considered in evaluation of any type of operation designed to treat duodenal ulcer. In the seven to nine years during which patients with extensive segmental resections have been followed, there have been no recurrent ulcers. After small segmental gastrectomy, only one patient developed a recurrent ulcer. This operation was done for gastric and marginal ulcer that had developed after a gastroenterostomy performed many years earlier. The recurrent ulcer, which was located in the gastric antrum, has now been treated by re-operation. Two additional patients in this group have had one episode of bleeding relatively soon after the operation, but repeated upper gastrointestinal x-ray examinations have failed to reveal ulceration in these patients, and both of them have been free from all symptoms since. It is conceivable that these episodes of bleeding may have resulted from erosion at the site where silk sutures had been placed in the mucosa at the time of operation. Following the occurrence of these two episodes, only absorbable suture material has been used in performing the mucosal suturing at the time of anastomosis. There have been no recurrent ulcers nor episodes of unexplained gastrointestinal bleeding following the moderate segmental operation.

The follow-up on patients with both the small and moderate segmental operations has been at most three years, and it is recognized that longer observation will be necessary to evaluate fully the protection afforded by these procedures. It does appear, however, that moderate segmental gastrectomy provides a sufficiently radical extirpation of the acid-pepsin secreting area of the stomach to control the ulcer diathesis. Analysis of gastric aspirate and the recurrent ulcer discussed above suggest that perhaps the small segmental operation, on the other hand, provides inadequate protection against re-ulceration.

Segmental gastric resection for treatment of gastric ulcer has been carried out in 35 patients. Twenty-one operations were extensive, ten were moderate, and four were small segmental operations. All ulcers were proved benign by histologic examination of each excised specimen, although in approximately 50 per cent of patients, the indication for operation had been suspected carcinoma; the rest of these gastric ulcers were operated upon because of medical intractability or recurrent bleeding. Table 8 shows the age and sex distribution of the 35 patients. While the number of patients in the different groups was small, the ranges of age were similar. Men predominated over women in a ratio of 3:1 in the extensive and small

segmental groups, and in a ratio of 3:2 among the moderate group.

TABLE 8
SEGMENTAL GASTRECTOMY FOR GASTRIC ULCER
DISTRIBUTION OF PATIENTS BY AGE AND SEX

	Extensive		Moderate		Small	
	Male	Female	Male	Female	Male	Female
No. of patients	16	5	6	4	3	1
Mean	53 yrs.	57 yrs.	65 yrs.	55 yrs.	54 yrs.	65 yrs.
Range	35-69	41-67	51-77	34-69	53-56	

Except for triple histamine gastric analysis (Table 9), laboratory evaluation of gastric secretion has thus far been carried out in relatively few patients who were operated upon for gastric ulcer. Mean free acid values in the preoperative period averaged 30° less for this group than for the duodenal ulcer group, there being only a few patients with greatly elevated acid values. Following operation for gastric ulcer there was a sharp drop in values for free hydrochloric acid in all groups; 84 per cent of the extensive segmental group showed achlorhydria to triple histamine stimulation after operation.

TABLE 9
TRIPLE HISTAMINE GASTRIC ANALYSIS
IN PATIENTS WITH GASTRIC ULCER

	Extensive			Moderate			Small		
	No. of Patients	Mean	Free Hydrochloric Acid Range	No. of Patients	Mean	Free Hydrochloric Acid Range	No. of Patients	Mean	Free Hydrochloric Acid Range
Preoperative	20	50°	0-135°	9	40°	0-85°	3	44°	36-50°
Postoperative	14	1.5°	0-14°	2	0°	0°	3	14°	0-42°

Postoperative unstimulated night gastric aspirate has been analyzed in only a few patients with gastric ulcer. In all instances there were very low values for pepsin, no free acid, high pH values, and insignificant degrees of digestion on perfusion of the cat esophagus. But since the majority of gastric ulcers thus far studied have shown little or no digestion of the cat esophagus *before* any treatment, this procedure offers less of a quantitative measure of achievement in surgical management of gastric ulcer than in duodenal ulcer.

The dumping syndrome has occurred with about the same frequency and distribution as it does following segmental gastrectomy

for duodenal ulcer: It has appeared most often after the extensive segmental operation, rarely following the moderate resection, and not at all after the small segmental operation. The previously discussed recurrent ulcer which appeared following a small segmental resection constitutes the single late complication of this character seen after segmental gastrectomy for benign ulcer disease.

Emergency gastric resection on the segmental principle has been performed 12 times. Six of these were extensive, five moderate, and one was a small segmental resection. Two of the patients were women and 10 were men. In all 12, the indication for operation was acute hemorrhage, resulting from duodenal ulcer in seven patients, from gastric ulcer in four patients, and from hemorrhagic gastritis in one patient. No quantitative data concerning gastric secretion have yet been collected for these patients, but there have been no recurrent ulcers in this group.

Nine segmental resections have been performed for esophagitis, two extensive, two moderate, and five small. One patient of the group was a woman, the rest were men. Age distribution was not remarkable as compared with that for patients with peptic ulcer, the mean age for the entire group being 60 years. Preoperative triple histamine gastric analysis was made for six of the patients. An average value of 57° of free hydrochloric acid was obtained with a range of from 0 to 103°. Postoperative free acid values ranged from 0 to 76° of free acid with an average value of 35°. Follow-up evaluation of six patients has been made: Results are excellent in three patients, good in two, and fair in one. Insufficient data have been accumulated thus far concerning overnight gastric secretion to permit critical evaluation on the basis of this test.

Operative Mortality:

Among the 12 patients who underwent emergency operation for acute gastrointestinal hemorrhage, there were no operative deaths; one patient, however, died later. This patient had undergone a moderate size segmental gastrectomy, although no source of bleeding could be demonstrated. Her bleeding ceased and her postoperative course was uncomplicated, but she was readmitted three days after hospital discharge with recurrent hemorrhage. She died at the time of re-operation. No bleeding source except a small esophageal ulcer could be demonstrated at either operation or at autopsy. If this death be attributed to the procedure, the mortality for emergency segmental gastrectomy is 8.3 per cent.

Following elective extensive segmental gastrectomy for ulcer, there has been one death as a result of perforation of the proximal pouch. After the moderate resection, one patient died following disruption of the anastomosis, and one patient died soon after the small segmental operation as a result of small bowel strangulation. One additional death — due to acute necrotizing pancreatitis — has occurred following a moderate size segmental gastrectomy performed concomitantly with cholecystectomy, common bile duct exploration, and sphincterotomy. Thus when elective segmental gastrectomy has been carried out as a single operation for peptic ulcer, the mortality rate has been 1.6 per cent; when all deaths after elective operation are considered, the mortality rate is 2.2 per cent. Following segmental resection for esophagitis, one patient died in the early postoperative period of pulmonary edema. Thus when all elective operations and all deaths are considered, the overall mortality rate for segmental resection is 2.5 per cent.

Discussion:

Segmental gastric resection has now been evaluated in a sufficiently large number of patients to justify the statement that it is an established safe operative procedure in treating acid-peptic disease. The operation can be utilized in surgical management of all forms of peptic ulcer save the antral and high cardiac ulcers, and it can also be used in definitive treatment of peptic esophagitis. It is equally applicable in elective and emergency situations and can be carried out with a mortality rate comparable to that experienced with the other types of gastric resection. Balance studies have shown that the procedure is followed by no impairment in fat absorption.¹² In the presence of extensive duodenal scarring and ulceration, the problem of difficult duodenal stump closure is circumvented. Retention of the antrum, rendered less sensitive by denervation, provides additional reservoir function, and also some possible protection against recurrent ulceration through the buffering capacity of its mucus secretions. An antral inhibitory function has been postulated but remains unproved.

Extensive segmental gastrectomy offers uniform protection against recurrent ulceration. This operation is followed, however, by weight loss and by the dumping syndrome in some patients. Since studies of gastric secretion have indicated that an operation this extensive may not be necessary to control the acid-peptic diathesis, segmental resections with removal of lesser segments of stomach have been in-

vestigated. Clinical evaluation and studies of gastric secretion to date indicate that the moderate segmental gastrectomy is adequate to prevent recurrent ulceration and at the same time is followed by a low incidence of postgastrectomy symptoms. Small segmental gastrectomy, although not followed by the dumping syndrome, does not appear to entail a sufficiently radical removal of secretory gastric mucosa to provide this protection.

Summary:

1. Since 1949, 197 segmental gastric resections have been carried out at the University of Minnesota Hospitals for treatment of duodenal and gastric ulcer and of peptic esophagitis.

2. Ninety-four patients have undergone extensive, 50 patients moderate, and 53 patients small segmental gastrectomy.

3. Clinical and laboratory evaluation of these patients has shown that the extensive segmental operation uniformly controls the acid peptic factor but is followed in some patients by distressing postgastrectomy symptoms. Small segmental gastrectomy is not followed by the postgastrectomy syndrome, but after this operation control of the ulcerating capacity of gastric juice is inadequate. Moderate segmental gastric resection appears to be satisfactory on both counts: Not only is the incidence of postgastrectomy symptoms low, but laboratory studies indicate fairly uniform reduction of acid and pepsin in gastric juice, and clinical experience has been uniformly satisfactory.

4. Operative mortality following elective segmental gastrectomy of all three types has been 2.5 per cent. Following emergency operation for hemorrhage, the mortality rate has been 8.3 per cent.

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Staff Meeting Report

Microsurgery in Otology*

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and

Donald E. Kilgore, M.D.‡

INTRODUCTION

A new era in otology is developing through the use of techniques under microscopic magnification employed for the following purposes:

1. To restore practical hearing in certain cases of clinical otosclerosis.

2. To remove chronic middle ear and mastoid disease, or their sequelae, and to restore a functioning tympanic cavity.

Initiated by European otologists, notably Holmgren in Sweden, microscopic magnification gained impetus in this country through Shambaugh's fenestration surgery and through the development by Zeiss, after suggestions from Lempert, of an operating microscope (often called an otoscope, Fig. 1).

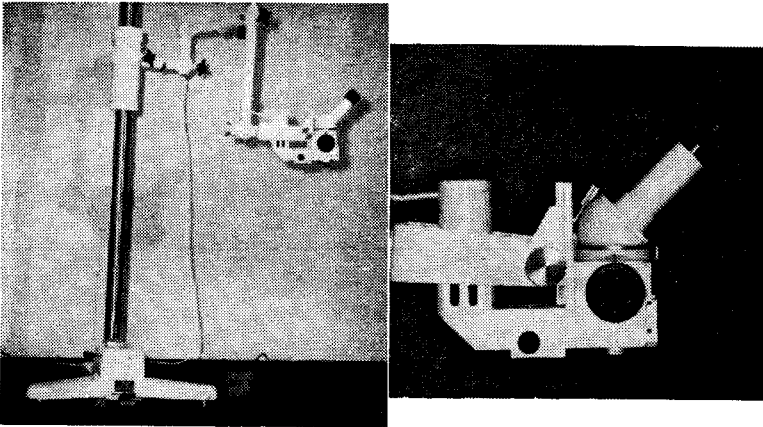


Fig. 1. Operating Microscope

*This report was given at the Staff Meeting of the University of Minnesota Hospitals on March 28, 1958.

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CLINICAL OTOSCLEROSIS

Otosclerosis is an osteodystrophy of unknown etiology originating in the bony capsule surrounding the membranous labyrinth. It is similar to but not identical with osteitis deformans and osteitis fibrosa cystica. Lempert and Wolff¹ have advanced a recent theory that otosclerosis is related to a familial inadequacy of the terminal blood supply to portions of the labyrinthine capsule.

Otosclerosis apparently occurs in all civilized races but is less common in the Negro than in the white race. It is also more common in women, the onset or increase of hearing loss occasionally being associated with pregnancy. Because it may exist as a silent lesion found only on microscopic study of the temporal bone, we properly differentiate between "histological otosclerosis" and "clinical otosclerosis."

Modern otologists believe that any progressive hearing loss of a conduction type that is not explained by middle ear disease is caused by an otosclerotic lesion that interferes with the movement of the footplate of the stapes. The principal symptom, which is hearing loss, begins insidiously, usually in the patient's young adulthood. Clinical otosclerosis has been seen in children (our youngest patient in whom this diagnosis was proved at surgery was 11 years old), but the disorder may not manifest itself until the fifth or sixth decade. Histological otosclerosis also has been found in small children; upon examining the temporal bones in 1,161 routine autopsies, Guild² found that the incidence of otosclerosis in children under five approximated 0.5 per cent.

Most patients with clinical otosclerosis complain of tinnitus, which in mild cases may be the most annoying symptom. About half the patients give a history of familial hearing loss, often insidious in onset. Usually the ear drum is normal or may appear somewhat thin, unless there has been inflammation of the middle ear to change the appearance of the drum. In some cases, a pinkish or reddish color may be seen through the drum; known as Schwartze's sign of the "promontory flush," it is thought to represent the vascularization of an otosclerotic focus on the inner wall of the middle ear. Despite occasional reports advocating some particular medication, no medical therapy has ever proved effective in arresting the disorder.

CURRENT STATUS OF SURGICAL THERAPY

Surgical therapy for otosclerosis is not new. Operations on the

stapes* for the relief of hearing loss that apparently was due to otosclerosis or to middle ear inflammation were performed more than a half century prior to the first report by Rosen of successful stapes mobilizations in 1953.¹⁷ Several European otologists, notably Passow, Barany, Jenkins, Holmgren and Sourdille, had worked out a fenestration operation years before Lempert first reported his success with a one-stage technique in 1938.¹⁸

The Fenestration

During the past 20 years the fenestration technique has probably reached the peak of its perfection,¹⁹ as numerous advances have practically overcome such earlier complications as postoperative labyrinthitis and bony closure of the fenestra. Today, experienced and skilled students of this operation would probably agree that in an *ideal* candidate for this surgery, there is at least a 90 per cent chance of a successful result—i.e., restoration of hearing to a level that is 1) practicable for ordinary social and economic needs, and 2) permanent until impairment occurs due to aging or to the development of otosclerotic foci elsewhere in the bony labyrinth than at the oval window.

This perfected technique entails exposing the horizontal semicircular canal through an endaural incision, followed by an exenteration of mastoid cells sufficient to expose the lateral aspect of the semicircular canal. It then involves the fashioning of a thin flap from the posterior canal wall continuous with the ear drum through Shrapnel's membrane, this flap being of a size and shape that will accurately cover the medial wall of the exposed attic of the middle ear and the exposed semicircular canals. After this has been accomplished, a fenestra is made in the ampullated end of the horizontal semicircular canal by the "dry technique," creating a cupola of bone which is removed by severing the edges with a sharp, spear-shaped knife. The cupola is lifted off, thus avoiding the bone dust that is created when a polishing burr completely exposes the membranous labyrinth. The flap is then fitted into position and practically "invaginated" at the edges of the fenestra.

The fenestration operation is a major surgical procedure requiring the patient to spend one week in the hospital and another two weeks of convalescence in which he must refrain from strenuous physical activity. The principal discomfort during convalescence, a dizziness

*These are described in a number of articles which are listed as nos. 3-16 at the end of this paper.

of variable amount, usually disappears in three weeks but sometimes persists in a minor degree indefinitely. Epithelization of the cavity created by the surgery is usually complete in three months. Thereafter, this cavity needs periodic care to remove desquamated epithelium, which if it has become moist may become infected. When the cavity is large, with recesses, there is a greater tendency to incomplete epithelization with persistent drainage.

Stapes Mobilization

Reference has been made to Rosen's first report in 1953¹⁷ of his revival of stapes surgery more than 50 years after its inception. In the more than four years since Rosen made his first report, the experience of many otologists dictates that stapes mobilization should be the primary surgical procedure whenever surgical therapy can be considered, including some cases in which the major surgical procedure of fenestration would be inadvisable.²⁰ The morbidity associated with fenestration surgery is much greater than with the stapes mobilization operation; however, the latter procedure is major surgery because of the minutiae of accurate, detailed technique necessary for optimal results. Both operations, however, demand an exact knowledge of anatomical minutiae, as well as exacting technique enhanced by considerable experience.

Stapes mobilization surgery is performed under local anesthesia which is excellent in most cases when induced by injection of a small amount of a mixture of 2 per cent xylocaine combined with 1:1000 epinephrine in the proportion of 1:4. The injection is made along the posterior half of the external canal at the junction of the membranous and osseous portions. A more or less curved incision is then made in the posterior canal 5-7 mm. from the margin of the drum. The flap thus created is elevated - with bleeding controlled - down to the annular ligament, which is then elevated from its bed, and the middle ear space is opened. The chordi tympani nerve, generally, the first structure encountered, is usually displaced or in rare cases severed for better visualization of the stapes. Commonly, however, some bone of the posterior rim of the canal wall - often a good deal - must be removed by a special curette to permit adequate visualization. Once this is obtained, the vital procedure of stapes mobilization is the next maneuver. In the early attempts at stapes mobilization this was tried by: 1) Simple pressure on the lenticular process of the incus; 2) Insertion of a pick into the margin of the head of the stapes, through which pressure and a rocking motion was

applied; 3) Pressure from a curved but blunt head against the anterior aspect of the neck of the stapes and in the direction of the stapedial tendon.

Possibly one-third of the stapes could be successfully mobilized by these maneuvers; in the rest the crura were usually fractured. These results led the otologist to attack the footplate directly. The most common site for the growth of otosclerotic bone to fix the footplate is at the anterior crus, and since this growth can usually be seen, mobilization is logically attempted first at this site. A pick inserted just in front of the anterior crus may loosen a limited focus there and offer adequate mobility. If it does not, the pick is inserted peripherally to this site and then behind the posterior crus and along the margins of the superior and inferior borders of the footplate where possible. Loosening at these sites, followed by slight pressure transmitted through the lenticular process of the incus above the joint or directly through the head, will often produce the mobility desired. When the pick is inserted at the rim of the footplate, a small amount of perilymph frequently escapes.

There still remains a small group of cases in which none of the procedures just mentioned will work. Rosen²¹ has reported encouraging results from making an opening in the footplate in such cases. The use of drills has been reported.* At present the mobilization techniques, rather than pressure techniques on the crura, are preferred for a direct attack on the footplate, with 50 to 70 per cent successes.

The advantages of the stapes mobilization operation when it works are:

1. The possibility of higher hearing levels and more natural hearing than can be obtained through fenestration surgery.
2. Very limited morbidity associated with a maximum of two days of hospitalization and a return to normal activity thereafter.
3. No postoperative care beyond removal of a slight amount of packing when this is used.

Although accidents in surgical technique resulting in facial paralysis and further impairment or even total loss of hearing in the affected ear have been reported, their incidence should be practically nil when this procedure is performed by an experienced surgeon.

*Tiny chisels are now being used at University Hospitals.

EXPERIENCE WITH THE SURGICAL TREATMENT OF CLINICAL
OTOSCLEROSIS AT THE UNIVERSITY HOSPITALS

In the 12½ years before January 1, 1958, 404 fenestration operations on selected patients were performed in this hospital, while in only two years before February 13, 1958, 300 stapes mobilization operations were performed. Several factors account for this considerable difference, but the principal one is the fact that stapes mobilization can be offered to those otosclerotic patients with a limited degree of sensory-neural (perceptive) hearing loss for whom the major procedure of fenestration would be inadvisable. This includes an older group of patients.

If there is a considerable gap between the curves for air and bone conduction (preferably 15 decibels or more in the speech frequencies of 500, 1000 and 2000), there is a chance of closing this gap by stapes mobilization. This procedure is worth a trial regardless of the age of the patient.

Then there are patients with evident middle ear adhesive processes in which the ear drum is lustreless and there is a question as to whether the conductive hearing loss is due to post-inflammatory changes or otosclerosis or both. Some of these patients should have an exploratory operation to determine the cause.

Results of Fenestration

Our follow-up of the fenestration cases is incomplete, and a statistical analysis of results would require a breakdown into periods in which different techniques were used. For example, at the beginning of this series a cartilaginous stopple was used to prevent closure of the window, but fixation of the stopple occurred in time, with the result that this procedure was abandoned. Removal of the fixed stopple occasionally led to improved hearing. Then a technique of burnishing the margins of the fenestra with lead, in order to retard osteogenetic closure, was applied without greater success. Another method involving actual invagination of the flap at the margins of the window with application of pressure packing became more or less standard procedure which is still used. Finally, the "dry technique," described on page 393, was adopted.

Some have reported their results on the basis of the suitability of the case for surgery, classifying the cases in A, B, and C, categories. The "A" group would include ideal patients from the hearing standpoint, with a pure conductive loss, probable complete fixation of the stapes, and an average age of 20-40 years. The "B" group consists

of patients with some impairment of nerve function and the "C" group of patients in whom there is more nerve impairment but in whom some gain in hearing could be expected because of a considerable gap between air and bone conduction for the low frequencies, with the bone conduction level above 30 decibels.

These 404 cases were referred to as "selected" cases because approximately 60 per cent were in category "A," and the other 40 per cent in "B." Using invagination of the flap and the dry technique, the operations performed on the "A" group resulted in restoration of practical hearing in 90 per cent of the patients. Our follow-up on this group is incomplete but we have reason to expect the gain to be maintained.

Results of Stapes Mobilization

The story of stapes mobilization is also one of change. We are now employing a different technique from that used in the 300 patients operated on before February 13, 1958. In approximately the first 150 patients operated on, successful mobilization was accomplished in about one-third. In all these the pressure was applied directly to the lenticular process over the joint to the head of the stapes or by pressure against the neck of the stapes in the direction of pull of the stapedius muscle. As experience grew, the percentage of successful results approximated 40 per cent. Then a direct attack on the footplate, in an attempt to loosen it by pressure of a pick through the otosclerotic process seemed to increase the successful results by another 10 per cent. From our limited experience to date with the present technique, which transfers the attack completely to the footplate, it appears that the percentage of successes will be substantially increased. Fortunately, otosclerotic bone seems to heal poorly and the fractured loosening to provide footplate mobility seems to be maintained in a high majority of cases. Less than 5 per cent of those who underwent the successful stapes mobilizations in our series have regressed to the preoperative level.

In the unsuccessful cases other means of getting sound impulses through the obstruction are being tried. These include: 1) a fenestration of the footplate and a covering of the opening thus made with a vein graft, after which a plastic "stapes" is attached to the lenticular process,²² and 2) the use of a tantulum wire for a columellar effect.²³ The wire is fastened around the lenticular process of the incus and a short length of it extends down beside the stapes and through a fracture line in the comminuted footplate. Fibrosis around this wire

is thought to give it enough attachment to transmit an impulse through to the vestibule below.

Rosen²¹ has reported substantially improved and even normal hearing following a "fenestration" of the footplate using a sharp needle perforator with a barbed end similar to a crochet hook or fish hook; this has occurred even when the ossicular chain has been broken by the removal and the incus and crura or when the footplate is immobile although the chain is intact. To date no one has corroborated Rosen's findings.

On the basis of present experience, there still remains a group for which fenestration offers the only chance of a restoration of practical hearing. The trial of stapes mobilization does not prevent a later fenestration.

ILLUSTRATIVE CASES

The following cases illustrate the end results in representative types and degrees of hearing loss. For brevity and clarity certain technical details have been omitted. Thus, while a complete hearing evaluation involves air and bone conduction audiometric testing, and speech audiometry plus tuning fork tests, only the air conduction curves are included in the audiograms that follow.

Age 53. History of hearing loss over a period of 18 years. Hearing tests indicated a bilateral loss for air conduction about equal in each ear with a moderate sensory-neural (perception) impairment. This audiogram

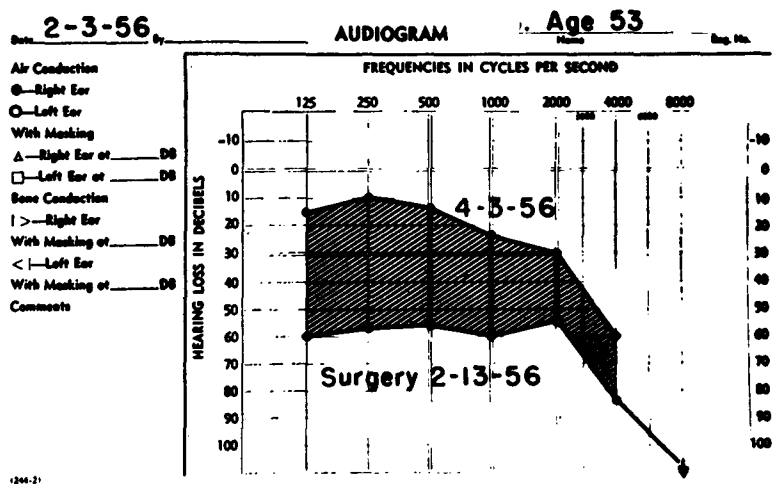


Fig. 2

(Fig. 2) indicates the hearing gain from a stapes mobilization on the right ear. The preoperative bone conduction level in this ear was at the level of air conduction following surgery, which indicates that the "air-bone gap" was closed.

The left ear was operated on a few weeks later without success.

Age 32. History of hearing loss in left ear for nine years. Hearing tests showed a marked conductive loss with some sensory-neural (perceptive) impairment (Fig. 3). The hearing in the right ear was within normal limits. (A sister of the patient had had a successful fenestration operation [by L.R.B.] several years earlier.) The following audiogram indicates the hearing gain from a stapes mobilization on the left ear, which closed the air-bone gap.

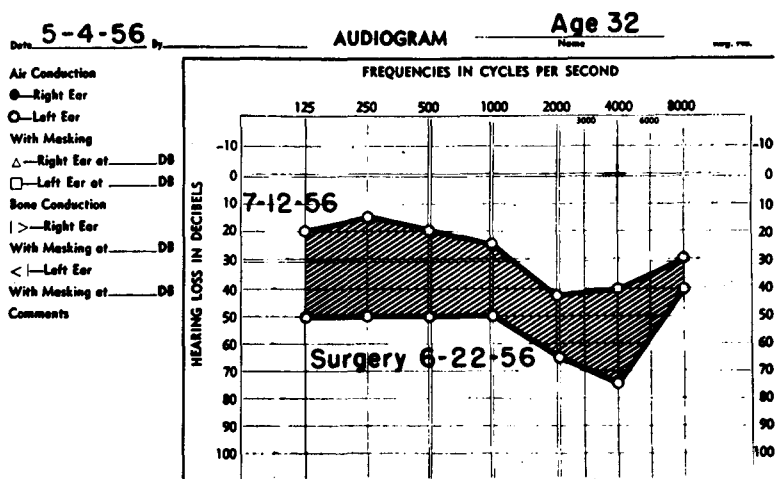


Fig. 3

Age 35. History of 13 years of progressive bilateral hearing loss. Hearing tests revealed a considerable bilateral loss of a conduction type about equal in each ear without any evidence of sensory-neural (perceptive) impairment (Fig. 4). A stapes mobilization on the right ear almost closed the air-bone gap and brought the hearing above the 30-decibel line through the speech frequencies, which is adequate for ordinary social and economic purposes. A stapes mobilization operation was performed on this patient's left ear on Feb. 11, 1958, but since the patient lives in northern Canada, we have not yet received the results of follow-up hearing tests.

M. M. Age 53. History of progressive bilateral hearing loss for more than 25 years. Hearing tests revealed considerable bilateral conduction loss with slight sensory-neural (perceptive) impairment in the left ear (Fig. 5).

THE MEDICAL BULLETIN

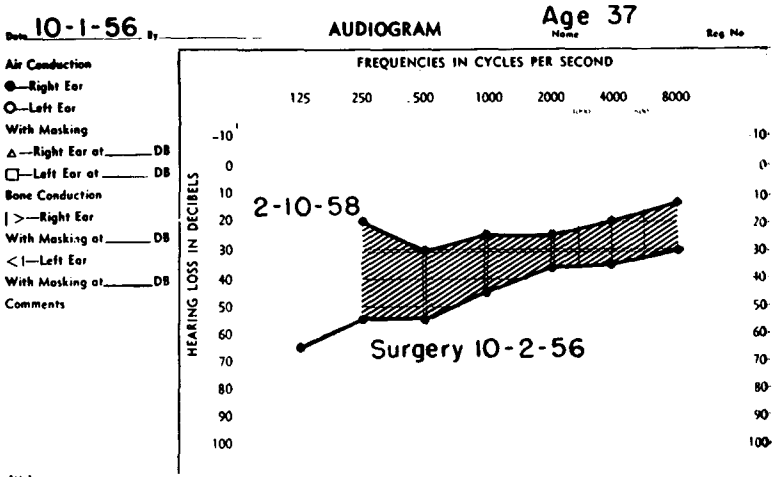


Fig. 4

A stapes mobilization operation was performed on the right ear on July 17, 1957, and another on the left ear on Sept. 18, 1957, with successful results, closing the air-bone gaps in each instance.

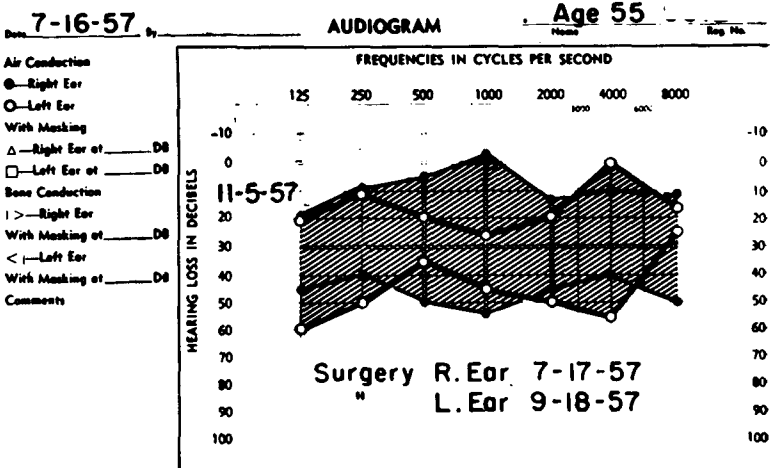


Fig. 5

Age 68. History of progressive hearing loss for approximately 30 years. The patient had worn a hearing aid for 25 years and was unable to communicate without it. Hearing tests revealed a severe loss in each ear, slightly more marked in the left, of a predominant sensory-neural (perceptive) character (Fig. 6). The patient was told that he was a poor candidate for surgical therapy, and that the most that could be hoped for would be the closing of his air-bone gap, which would not enable him to discard his hearing aid. He nevertheless elected to try the surgery, and it partially closed his air-bone gap. He reports that he gets a much improved performance from his aid on this ear and has asked to have the operation performed on the other ear.

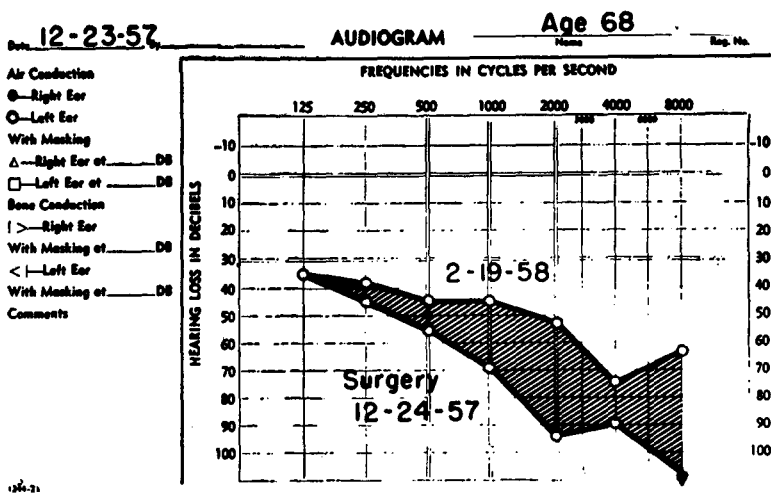


Fig. 6

THE RESTORATION OF TYMPANIC FUNCTION DAMAGED BY
 CHRONIC MIDDLE EAR AND MASTOID DISEASE

Surgical attempts at restoring function of the middle structures for the conduction of sound are not new, but the recent work of Zöllner^{24,25} and Willstein^{26,27} has given them greater impetus. The magnification afforded by the operating microscope, new techniques of skin grafting, and the support of antibiotics have all contributed to the success of these procedures. In modern terms these two new procedures are known as myringoplasty and tympanoplasty.

Myringoplasty

Chronic perforations of the ear drum are very common. Simple

perforations in *dry* ears that persist because the epithelium of the outer layer has grown over the margin can usually be closed by cauterization of the margins with trichloroacetic acid and the placing of a patch over the perforation. Several cauterizations may be necessary.^{28,29}

In the larger perforations or those that fail to heal over after cauterization and patching, the operation known as *myringoplasty* will often effect satisfactory closure to restore normal tympanic function if the ossicular chain can work normally.

The technique involves the following steps:

1. The outer (squamous cell) layer of the drum is removed with special instruments under microscopic magnification for an area of about a millimeter around the periphery of the perforation.

2. A full thickness graft of skin from the postaural area is removed and trimmed to fit accurately the circumference of the denuded area. Gelfoam® is used to fill the middle ear space to support the graft, and packing is placed on the outside to keep the graft in position. If the graft takes, and if the ossicular chain moves normally, a good degree of tympanic function will result.

When there is more extensive damage than perforation of the drum, other reconstructive measures, collectively known as tympanoplasty, are used. If the damage is to the conductive mechanism and if the Eustachian tube has a normal function, plastic procedures on the tympanum can substantially increase the patient's hearing ability. While the extent of the operation depends, of course, on the needs of the individual patient, the general procedure in a dry ear entails:

- 1). Removal of scar tissue that might interfere with the functioning of any remaining portions of the ossicular chain and with the functioning of an air-containing tympanic space as it relates to the round window.

- 2). Accurate placement of a graft to serve as an ear drum. This must be in contact with remaining functioning portions of the ossicular chain, to create the outer wall (ear drum) of this air-containing tympanic space related to the round window. This may require an expanded tympanoplasty with the new ear drum created by a skin graft in contact with the incus after any remaining malleus has been removed; or, an end result in which all the ossicles are removed and a graft creates a minor air-containing space at the round window; or, in addition to the creation of this space at the round window, the graft covers a window made in the horizontal semicircular canal to bypass an obstructed oval window function.

There is a tendency to type these procedures according to the extent of surgical work done as follows: Type I refers to simply grafting an ear drum perforation and is actually a myringoplasty. Type II is an expanded myringoplasty in which the malleus has been removed in the course of disease, or by the surgeon, and the complete drum is replaced by a graft in contact with the incus. Type III, in which the stapes alone remains of the ossicular chain and the drum is completely replaced by a graft which contacts the stapes, and a reduced air-containing tympanic cavity function. Type IV, in which a small air-containing cavity is created by a graft attached to the promontory, extending over the tympanic orifice of the Eustachian tube, and attached to the outer inferior margin of the middle ear space. The stapes is gone in these cases but an oval window membrane functions. Type V, in which the oval window does not function and a fenestra is made in the horizontal canal. An extensive skin graft creates a minor tympanic cavity as in Type IV and also covers the newly created window in the horizontal canal.

When the ear is wet with drainage from infected mucous membrane in the middle ear, in the mastoid antrum or cells, or from actual bone disease, the painstaking removal of all diseased tissue is required before a graft will be successful. Adequate epithelization of this newly created air-containing space is a problem. In certain cases the eradication of the active chronic disease should be done in one stage and the tympanoplasty in a second stage.

Adults are more suitable candidates for this form of surgery than are small children because of the greater susceptibility of children to respiratory and other infections.

SUMMARY

1. A new era in otology is developing through the use of microscopic magnification employed to restore practical hearing through surgery by mobilizing the stapes in clinical otosclerosis.

2. The use of this magnification together with our increase knowledge about the requirements of a functioning tympanic air space make possible restoration of hearing in certain cases of active, chronic middle ear disease or its sequelae.

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Coming Events

- May 5-9 Continuation Course in Electrocardiography
for General Physicians and Specialists
- May 8 A.O.A. LECTURE: *Retrospective Gastro-
scopic Glimpses*; Speaker: DR. O. H. WAN-
GENSTEEN, Chairman and Professor, Depart-
ment of Surgery, University of Minnesota
Medical School; Mayo Memorial Auditorium;
8:00 P.M.
- May 12-16 Continuation Course in Proctology for General
Physicians
- May 22 Medical Six O'Clock Dinner; Main Ballroom,
Coffman Memorial Union; 6:30 P.M.

WEEKLY CONFERENCES OF GENERAL INTEREST

Physicians Welcome

- Monday, 9:00 to 10:50 A.M. OBSTETRICS AND GYNECOLOGY
Old Nursery, Station 57
University Hospitals
- 12:30 to 1:30 P.M. PHYSIOLOGY-
PHYSIOLOGICAL CHEMISTRY
214 Millard Hall
- 4:00 to 6:00 P.M. ANESTHESIOLOGY
Classroom 100
Mayo Memorial
- Tuesday, 12:30 to 1:20 P.M. PATHOLOGY
104 Jackson Hall
- Thursday, 11:30 A.M. to 12:30 P.M. TUMOR
Todd Amphitheater
University Hospitals
- Friday, 7:45 to 9:00 A.M. PEDIATRICS
McQuarrie Pediatric Library,
1450 Mayo Memorial
- 8:00 to 10:00 A.M. NEUROLOGY
Station 50, University Hospitals
- 9:00 to 10:00 A.M. MEDICINE
Todd Amphitheater,
University Hospitals
- 1:30 to 2:30 P.M. DERMATOLOGY
Eustis Amphitheater
University Hospitals
- Saturday, 7:45 to 9:00 A.M. ORTHOPEDICS
Powell Hall Amphitheater
- 9:15 to 11:30 A.M. SURGERY
Todd Amphitheater,
University Hospitals

For detailed information concerning all conferences, seminars, and ward rounds at University Hospitals, Ancker Hospital, Minneapolis General Hospitals, and the Minneapolis Veterans Administration Hospital, write to the Editor of the BULLETIN, 1342 Mayo Memorial, University of Minnesota, Minneapolis 14, Minnesota.